Smart water-use feedback: Options, preferences, impacts, and implications for implementation

Ariane Liu
Institute for Sustainable Futures
University of Technology Sydney

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

Smart water metering (SW metering) is enabling the water industry to enter into the digital age and to embrace new levels of water usage awareness, data analysis and communication. While implementations have been advancing internationally, less progress has been made in extending the benefits of this data and information to access by householders, including in Australia. This thesis investigates the opportunity for more detailed information and feedback on household water consumption by: (i) conceptualising the different options for the presentation of detailed feedback enabled via SW metering (ii) uncovering householder interests and preferences; (iii) measuring the various impacts of detailed feedback on householders and their consumption of water; and (iv) developing an implementation framework. These issues are investigated in relation to furthering implementations and the contribution of SW metering towards more sustainable urban water management (SUWM).

This empirical research was conducted via two trials in New South Wales, Australia to address the urgent need for improved knowledge and experiences of the issues relating to the provision of detailed water-use feedback via SW metering. The 'Home Water Update' (HWU) study provided detailed household water- and end-use feedback via paper-based reports. The 'My Home Our Water' (MHOW) study provided consumption feedback according to time of use in near real-time via an online portal. A mixed methods approach was used to analyse the trials using smart water meter data, surveys and interviews.

This research shows that providing more detailed water-use feedback through SW metering generates significant householder interest and produces measurable savings (up to 8% in the HWU (paper) study and 4.2% over the longer term in the MHOW (online) study). Moreover, the wide range of options for detailed feedback enabled by SW metering identified in the research—together with the variety found in householder preferences for and responses to detailed feedback—suggests that greater customisation would further elevate the value of feedback to customers and improve engagement.

The implementation framework developed further provides a detailed overview of the key elements for decision-making for detailed water-use feedback programs, categorised as strategic, practical and evaluative considerations. Overall, the research findings cover a broad range of aspects critical to the design of future trials and large-scale roll-outs of SW metering and detailed feedback and the promotion of use that foster more SUWM. For wider industry adoption of detailed water-use feedback programs enabled via SW metering, the importance of the following is underlined (i) conducting quality, robust research and its implications for

project resources; (ii) facilitating knowledge sharing in order to further the water industry's understanding and experience regarding methods and approaches to feedback provision; (iii) building knowledge on how to address heterogeneity among customers is recommended in order to customise approaches to feedback provision (e.g. via a large scale preferences survey and subsequent experimentation with greater levels of customisation, particularly with robust scaled research trials); and (iv) developing the business case for detailed water-use feedback provision by fully documenting methods and making these available for wider evaluation and industry recommendations and improvements. Further developments in this direction, using the implementation framework, will enable the water industry to work towards large-scale implementation of detailed feedback provision which take more full advantage of the customised options made possible via SW metering and the digital age.

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List of publications

This 'hybrid' thesis format is presented as a series of papers (chapters 3, 4, 5 and 6) together with an exegesis comprising introduction and methodology chapters (1 and 2) and implications and conclusions (chapters 7 and 8). The thesis includes the following papers, which are referred to in this thesis by their Roman numerals:

I. **Liu, A.,** Giurco, D., Mukheibir, P. 2015, 'Motivating metrics for household water-use feedback', *Resources, Conservation and Recycling*, vol. 103, pp. 29-46. DOI: 10.1016/j.resconrec.2015.05.008.

II. **Liu, A.,** Giurco, D., Mukheibir, P. 2016, 'Urban water conservation through customised water and end-use information'. *Journal of Cleaner Production,* vol. 112, pp. 3164-3175. DOI: 10.1016/j.jclepro.2015.10.002.

III. **Liu, A.,** Giurco, D., Mukheibir, P., Mohr, S., Watkins, G., White, S. 'Online water-use feedback: household user interest, savings and implications' (Submitted manuscript under review).

IV. **Liu, A.,** Giurco, D., Mukheibir, P., White, S. (in press), 'Detailed water-use feedback: a review and proposed framework for program implementation', *Utilities Policy*. DOI: 10.1016/j.jup.2016.09.002.

Author's contributions to the papers

Ariane Liu led the development of research ideas, methods, data collection and analysis and wrote the manuscripts and revisions in response to the peer reviewers' comments. The concepts in the papers were discussed with Damien Giurco and Pierre Mukheibir, who also reviewed the manuscripts within their supervisory roles, as well as with Graeme Watkins and Stuart White. The statistical analysis in Paper III was provided by Steve Mohr.

Other publications not included in this thesis

The following journal and conference papers were also produced during the course of the author's doctoral research.

V. Boyle, T., Giurco, D., Mukheibir, P., **Liu, A.,** Moy, C., White, S., Stewart, R.A. 2013, 'Intelligent metering for urban water: A review', *Water*, vol. 5, no. 3, pp. 1052-1081.

VI. **Liu, A.,** Giurco, D., Mukheibir, P., Watkins, G. 2013, 'Smart metering and billing: Information to guide household water consumption', *AWA Water*, vol. 40, no. 5, pp. 73-77;
Previously in Proceedings of the 2013 AWA Water Efficiency, Education and Skills Conference, 5-7 March 2013, Sydney, Australia.

VII. **Liu, A.,** Giurco, D., Mukheibir, P. 2014. 'Online household water portal: User interactions and perceptions of water use', In Proceedings of the 2014 SWGIC, Smart Water Grid International Conference, Book of Abstracts, pp. 102–8, 25-27 November, 2014, Incheon, South Korea. *Awarded a 'Certificate of excellent oral presentation of an excellent paper' in the SWGIC best paper awards.*

VIII. **Liu, A.,** Giurco, D., Mukheibir, P. 2015, 'Household water-use feedback: moving forwards towards sustainable urban water'. In Proceedings of the International Conference on Sustainable Water Management 2015, 29 November to 3 December, 2015, Murdoch, WA Australia.

IX. **Liu A.,** Giurco, D., Mukheibir, P. in press, 'Advancing household water-use feedback to inform customer behaviour for sustainable urban water', *Water Science and Technology: Water Supply*. DOI: 10.102166/ws.2016.119.

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Abbreviations

ARC	Australian Research Council
AUD	Australian Dollar
HWU	Home Water Update (paper-based water and end-use feedback reports)
IHD	In-home display
ISF	Institute for Sustainable Futures
L/hh/d	Litres per household per day
MCW	MidCoast Water
MHOW	My Home Our Water (online water-use feedback portal)
SUWM	Sustainable urban water management
SW (metering)	Smart water (metering)

Glossary

End-use feedback	Feedback disaggregated by water-use fixtures, appliances or other uses (e.g. taps, toilet, shower, washing machine, outdoors, leaks)
Near real-time feedback	Feedback provided within 24 hours of consumption taking place
SW metering	Smart water (SW) metering is advanced metering which involves the collection of water consumption data at highly frequent intervals (e.g. of minutes or seconds)
Time of use	Time of water consumption, for example, 07:03 AM
Water-use feedback	Customised information on water consumption